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August 18, 2014

Sharon DeMeo
U.S. Environmental Protection Agency – Region 1
5 Post Office Square, Suite 100 (OEP06-1)
Boston, MA 02109-3912

Submitted via FedEx overnight delivery

Dear Ms. DeMeo,

The Electric Power Research Institute (EPRI) appreciates the opportunity to provide comments to the Environmental Protection Agency on the draft determination of technology-based effluent limits for FGD wastewater at Public Service of New Hampshire Merrimack Station. EPRI focused our analyses on the physical/chemical and vapor compression evaporation (VCE) FGD wastewater treatment cost effectiveness assessment. We also have included a summary update of our FGD wastewater treatment pilot studies evaluating biological treatment. Please find attached two hard copies of our comments. Advise if you would need an electronic pdf file of our comments.

If you have any questions, please contact me at 650 855 2362 or pchu@epri.com.

Sincerely,

Paul Chu

Principal Technical Leader

Environment Sector

EPRI

# EPRI Comments on the Revised Draft Determination of Technology-Based Effluent Limits for the Flue Gas Desulfurization Wastewater at Merrimack Station in Bow, New Hampshire

## Introduction

The Electric Power Research Institute (EPRI) is providing technical comments to Region 1 of the United States Environmental Protection Agency (EPA) on the draft permit for wastewater discharges for the Public Service of New Hampshire (PSNH) Merrimack Station. On February 28, 2012, EPRI had provided technical comments to the earlier, proposed permit dated September 30, 2011. These earlier comments focused on the cost-effectiveness evaluation for physical/chemical and biological treatment for FGD wastewater.

EPRI was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together member organizations, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of power generation, delivery, and use, including health, safety, and environment. EPRI has been active in characterizing flue gas desulfurization (FGD) wastewaters and evaluating treatment technologies since 2006. This work includes characterization of FGD wastewaters, evaluation of mercury and selenium chemistry in FGD wastewaters, and the evaluation of physical/chemical, biological, and vapor compression evaporation (VCE) wastewater treatment approaches.

## FGD Wastewater Treatment Cost-Effectiveness Evaluation

EPRI reviewed the Revised Draft PSNH Merrimack permit dated April 18, 2014 and associated fact sheet. EPRI conducted an evaluation of the cost effectiveness of FGD wastewater treatment using EPA's established criteria for the following technologies: physical/chemical and VCE treatment. The cost effectiveness calculations were performed by estimating the pollutant removals for each technology and comparing these removals with the costs of the technologies. The pollutant removals and costs for the physical/chemical and the vapor compression evaporation plus crystallization (VCE) wastewater treatment systems are included in Table 1. Incremental VCE removal is defined here as the removal of all pollutants in the effluent from the physical/chemical treatment process. The supporting calculation details are provided in the Appendix A.

TABLE 1

Merrimack Cost Effectiveness for Physical/Chemical and VCE Wastewater Treatment

| | Removal (TWPE per year) | Capital Cost (Million dollars) | Operation & Maintenance Cost (Million dollars per year) | Total Annualized Cost (Million dollars per year) | Cost Effectiveness Ratio (Dollars per TWPE) | Capital Cost (Million 1981 dollars) | Operation & Maintenance Cost (Million 1981 dollars per year) | Total Annualized Cost (Million 1981 dollars per year) | Cost Effectiveness Ratio (1981 Dollars per TWPE) |
|---|---|---|---|---|---|---|---|---|---|
| **Physical/Chemical** | 4,205 | 19.3 | 1.8 | 3.7 | 871 | 7.3 | 0.7 | 1.4 | 331 |
| **Incremental VCE** | 478 | 35.3 | 2.4 | 5.7 | 11,992 | 13.4 | 0.9 | 2.2 | 4,563 |

TWPE: Toxic Weight Pound Equivalent

EPRI's technical comments on FGD wastewater treatment cost-effectiveness are summarized as follows:

1. Based on our calculations, approximately 90% of PSNH Merrimack's total pollutant removal (calculated as toxic weighted pound equivalents [TWPE]) is accomplished by the physical/chemical wastewater treatment system. Only 10% of the total pollutant removal can be attributed to the VCE system.

2. The cost/TWPE ratio for physical/chemical treatment is $324/TWPE (in 1981 dollars, a standard measure used by EPA in evaluating cost effectiveness). The cost/TWPE ratio for VCE treatment is $4,563/TWPE in $1981.

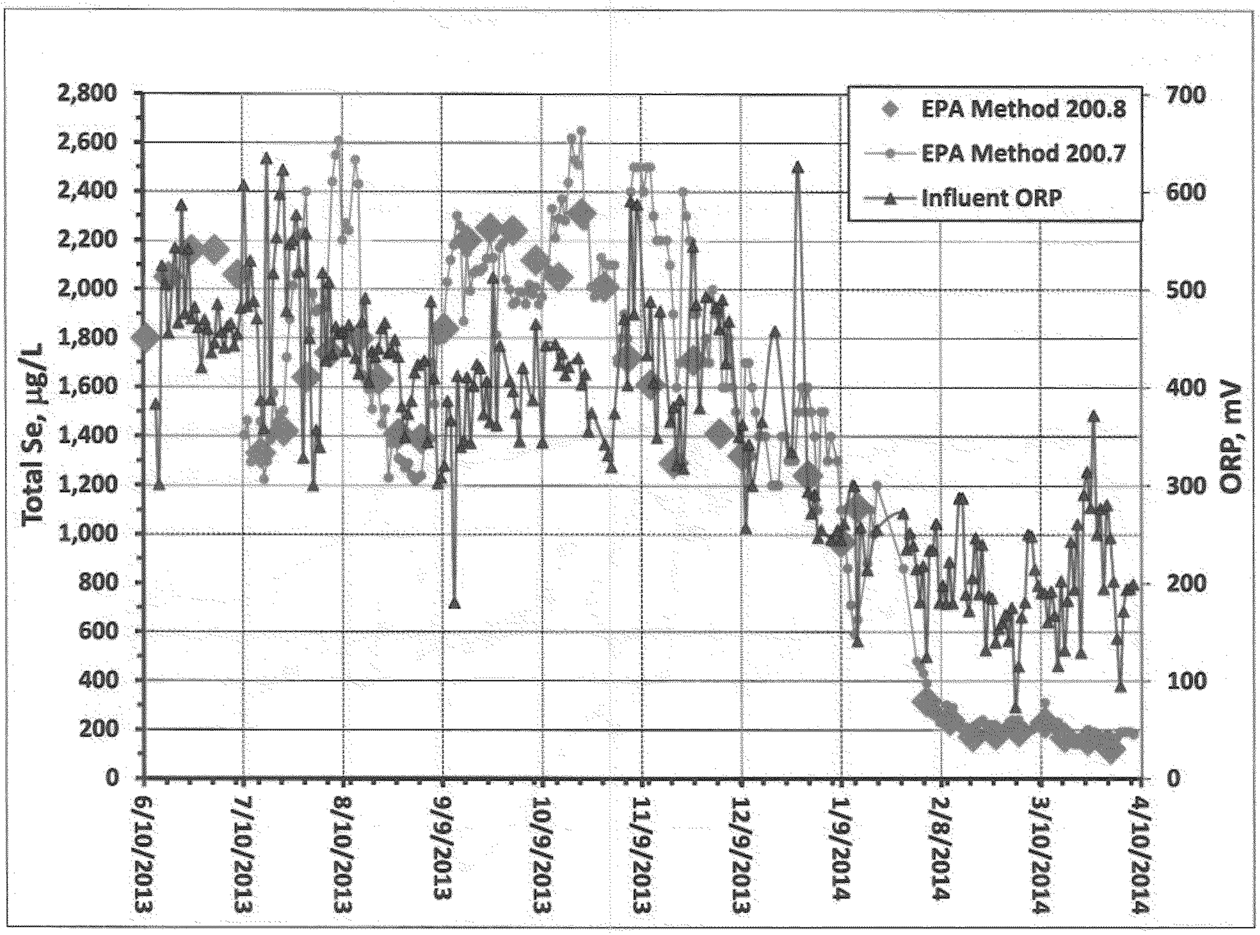
## EPRI Pilot Biological Wastewater Treatment Studies

In related developments, EPRI recently completed a ten-month pilot test evaluation of three biological treatment technologies at a coal-fired power plant located in the southeastern US. This work was not conducted at the Merrimack Station. The objective of these studies was to evaluate performance of various FGD treatment technologies and their capability to meet the proposed Effluent Limitation Guidelines (ELG) numeric standards for selenium, mercury, arsenic and nitrate/nitrite. These pilot studies were conducted using a slipstream of FGD wastewater from the power plant's existing FGD physical/chemical wastewater management system.

### Variability of FGD Water Chemistry; Impact on FGD Wastewater Concentrations

For this southeastern power plant, the FGD wastewater quality was highly variable in oxidation-reduction potential (ORP), pH, alkalinity; all of these factors significantly impacted trace metal concentrations in the FGD wastewater. Figure 1 summarizes the influent selenium data (using EPA Method 200.7 as well as 200.8) in relation with the ORP. In the first "phase" of the pilot studies, the ORP was 400-500 mV and the selenium concentrations were about 2000 ppb. In December 2013, the FGD absorber was removed from service for repair work. In January 2014, the absorber operating control points were re-programmed. In addition, the plant started burning a different coal. These changes in plant operations appear to correlate to changes observed in FGD water quality. Near the end of December 2013, the ORP was approximately 200 mV and the selenium concentrations were in the 200 ppb range. Similar trends were observed for mercury, nitrate and other trace metals. These results indicate that FGD water chemistry may vary significantly with plant operations and coal burned.

FIGURE 1 – IMPACT OF ORP ON INFLUENT SELENIUM CONCENTRATIONS

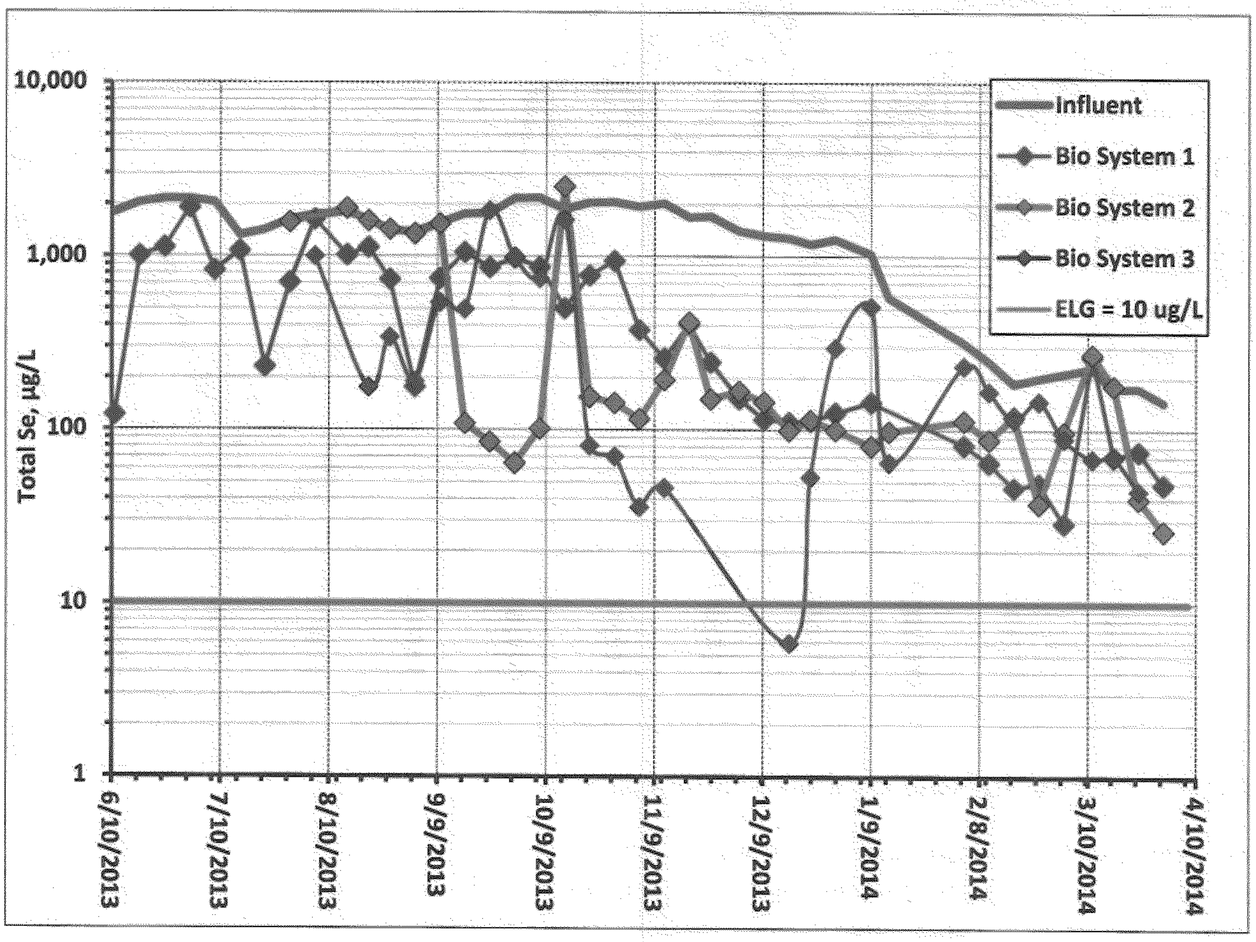



## Impact of FGD Wastewater Treatment Performance

More importantly, the FGD water quality impacted the ability to treat the FGD wastewater, with the most significant impact on selenium. Figure 2 summarizes the selenium measurement data using EPA Method 200.8 (which incorporated dynamic reaction cell technology to minimize polyatomic interferences) for the three biological treatment technologies. Because of the significant variability observed in FGD water quality, the principal investigators attempted to manage the FGD water chemistry to maximize selenium removal by adjusting the ORP, pH, and alkalinity as well as installing a pilot physical/chemical pretreatment system employing lime desaturation and ferrous chloride precipitation. Some of these water pretreatment steps led to improved selenium removals. However, the FGD water in the initial test phase - before the operational changes - was extremely challenging to remove selenium to even 100 ppb, much less the proposed 10 ppb ELG numeric limit. After the FGD absorber modifications and a change to a different coal, the influent selenium levels were much lower and all three biological treatment technologies were able to achieve lower selenium effluent levels – although still not consistently meeting the 10 ppb selenium proposed ELG limit, with the exception of one data point.

These results indicate that the FGD water chemistry can be highly variable, can be impacted by plant operations and is likely site-specific. Based on our current state-of-science, this is important as the FGD water chemistry may ultimately impact overall selenium treatment performance in biological treatment systems as well as the ability for some facilities to consistently meet the proposed 10 ppb selenium ELG numeric standard.

FIGURE 2 – SUMMARY OF BIOLOGICAL SELENIUM TREATMENT REMOVAL - EPRI PILOT STUDIES



# Appendix A: FGD Wastewater Treatment Cost-Effectiveness Analysis

## Introduction

This Appendix provides details on how EPRI estimated cost-effectiveness for FGD wastewater treatment. Physical/chemical and vapor compression evaporation (VCE) FGD wastewater treatment pollutant removals were estimated and the costs associated with each system were compared with their removal rates. Cost estimates are based on information provided by PSNH Merrimack.

## Pollutant Removals Calculation Methodology

Pollutant removals were defined as the estimated amount of contaminants removed from wastewater. The estimated contaminants removed were calculated both as concentrations and toxic-weighted pound equivalents (TWPE). TWPE factors are used by the United States Environmental Protection Agency (EPA) to express the relative toxicity of pollutants. Calculations use the concentration of contaminants in the water, wastewater flow, and toxic weighting factors (TWF). Data from PSNH Merrimack sampling were used in the calculations.

## Summary of Available Data

EPRI's evaluation used data from two sampling episodes at PSNH Merrimack. The wastewater treatment system influent was based on a 5-day sampling episode that ranged from late December 2011 through early January 2012. The physical/chemical treatment system effluent data were based on 6 data samples ranging from January 2012 through March 2012. Two sample points occurring on the same day were averaged first before averaging the remaining four data points. Non-detect data were treated as half of the method detection limit. Analytes that were not included as part of the plant PSNH sampling episodes were estimated with data based on the following documents:

- Physical/Chemical Influent: *Memorandum: Technology Option Loads Calculation Analysis for Steam Electric Detailed Study* (ERG, 2009)
- Physical/Chemical Influent and Effluent: *Technical Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA, 2013)

The influent and effluent data were averaged respectively and multiplied by the average flow rate at Merrimack (44 gpm) and TWF to calculate TWPE per year. The flow per year was based on PSNH's estimate of operating roughly 40 percent of the time. The available data are summarized in Tables 1 and 2. Table 3 summarizes the averaged influent and effluent values and estimated pollutant removals by physical/chemical (pollutants in physical/chemical influent minus physical/chemical effluent) and by VCE (removal of pollutants in physical/chemical effluent) systems.

## Pollutant Removal Estimates

For clarity, the following terms are used:

- Physical/Chemical removal: The estimated amount of pollutants removed via physical/chemical treatment (i.e. physical/chemical influent minus physical/chemical effluent)
- VCE removal: The amount removed via VCE treatment (i.e. removal of all remaining pollutants in the physical/chemical treatment system effluent). It is noted that this is a conservatively high estimate of pollutant removal as PSNH is required to operate with a small discharge of wastewater (which is currently managed offsite). If this wastewater discharge was counted the cost-effectiveness would be an even higher $/TWPE value.

The pollutant removal calculation followed EPA's methodology outlined in the *Technical Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA, 2013) pollutant removal calculations. However, since the calculation included plant specific data, our estimate had three deviations from EPA's methodology as follows:

- Actual sampled plant influent/effluent data were used
- Physical/chemical removal was calculated using the untreated FGD purge as the influent to the physical/chemical treatment system
- VCE treatment system benefits were calculated by removing all pollutants (i.e. VCE effluent as 0)

A summary of the estimated benefit calculation for PSNH Merrimack is presented in Table 4.

TABLE 1
Merrimack Physical/Chemical Influent Data and Average Concentrations in mg/L

| Analyte | Sample Day 1 12/20/11 – 12/21/11 | Sample Day 2 01/03/12 – 01/04/11 | Sample Day 3 01/04/12 – 01/05/12 | Sample Day 4 01/05/12 – 01/06/12 | Sample Day 5 01/06/12 – 01/07/12 | Average |
|---|---|---|---|---|---|---|
| Ammonia | | | | | | 5[a] |
| Nitrate Nitrite as N | | | | | | 32.9[a] |
| Chloride | 9100 | 10000 | 10000 | 10000 | 11000 | 10020 |
| Sulfate | 2200 | 3200 | 2800 | 3200 | 3100 | 2900 |
| Cyanide, Total | | | | | | 0.0117[b] |
| Aluminum | 65.5 | 45.2 | 708 | 85.8 | 84.3 | 198 |
| Antimony | 0.0178 | 0.0128 | 0.0145 | 0.0152 | 0.0152 | 0.0151 |
| Arsenic | 0.224 | 0.206 | 0.232 | 0.221 | 0.233 | 0.223 |
| Barium | 0.579 | 0.582 | 0.657 | 0.407 | 0.301 | 0.505 |
| Beryllium | 0.00739 | 0.00978 | 0.0122 | 0.0112 | 0.0101 | 0.0101 |
| Boron | | | | | | 208[a] |
| Cadmium | 0.0159 | 0.0198 | 0.0208 | 0.0206 | 0.0201 | 0.019 |
| Calcium | | | | | | 4,850[a] |
| Chromium | 0.665 | 0.535 | 0.718 | 0.608 | 0.659 | 0.637 |
| Chromium (VI) | 0.088 | 0.207 | 1.35 | 1.91 | 0.0442 | 0.720 |
| Cobalt | | | | | | 0.0875[a] |
| Copper | 0.279 | 0.314 | 0.357 | 0.338 | 0.341 | 0.326 |
| Iron | 116 | 104 | 137 | 117 | 128 | 120 |
| Lead | 1.89 | 1.65 | 1.7 | 1.51 | 1.56 | 1.66 |
| Magnesium | 870 | 970 | 948 | 1010 | 968 | 953 |
| Manganese | 22.3 | 25.5 | 25.9 | 22.1 | 23.3 | 23.8 |
| Mercury | 0.183 | 0.288 | 0.303 | 0.239 | 0.277 | 0.258 |
| Molybdenum | | | | | | 0.124[a] |
| Nickel | 1.03 | 1.08 | 1.16 | 1.03 | 0.992 | 1.06 |
| Selenium | 2.93 | 2.71 | 2.86 | 2.52 | 2.68 | 2.74 |
| Silver | 0.000781 | 0.00015 | 0.00015 | 0.00015 | 0.00015 | 0.000276 |
| Sodium | | | | | | 612[a] |
| Thallium | 0.02 | 0.0128 | 0.014 | 0.0155 | 0.0178 | 0.016 |
| Tin | | | | | | 0.0115[a] |
| Titanium | | | | | | 0.608[a] |
| Vanadium | | | | | | 0.344[a] |
| Zinc | 5.1 | 3.75 | 4.56 | 4.11 | 3.91 | 4.29 |

a: Data gap filled with *Memorandum: Technology Option Loads Calculation Analysis for Steam Electric Detailed Study* (ERG, 2009)

b: There was no available data for cyanide in FGD influent. There is available data for cyanide in the physical/chemical treatment system effluent (Table 2). Cyanide is not typically removed by physical/chemical treatment, therefore, the value for influent is set equal to the data available for physical/chemical treatment system effluent.

TABLE 2

Merrimack Physical/Chemical Effluent (VCE Influent) Data and Average Concentrations in mg/L

| Analyte | Sample 1/5/12 | Sample 1/5/12 | Average of 1/5/12 samples | Sample 1/26/12 | Sample 2/2/12 | Sample 2/9/12 | Sample 3/2/12 | Average |
|---|---|---|---|---|---|---|---|---|
| Ammonia | 0.92 | | 0.92 | 1.2 | 1.1 | | | 1.07 |
| Nitrate Nitrite as N | 100 | | 100 | 68 | 65 | | | 77.7 |
| Chloride | 11000 | | 11000 | 9500 | 9300 | | | 9933 |
| Sulfate | 1200 | | 1200 | | 1200 | | | 1200 |
| Cyanide, Total | 0.02 | | 0.02 | 0.01 | 0.005 | | | 0.0117 |
| Aluminum | 0.0411 | 0.04 | 0.0406 | 0.04 | 0.218 | 0.1 | | 0.100 |
| Antimony | 5.20E-04 | 4.08E-04 | 4.64E-04 | 7.58E-04 | 1.55E-03 | | | 9.24E-04 |
| Arsenic | 0.00498 | 0.00851 | 0.00675 | 0.00956 | 0.0121 | 0.00375 | 0.00812 | 0.00806 |
| Barium | 0.3 | 0.24 | 0.27 | 0.208 | 0.243 | | | 0.240 |
| Beryllium | 5.22E-04 | 6.00E-04 | 0.000561 | 0.0006 | 0.0015 | | | 8.87E-04 |
| Boron | 980 | 493 | 737 | | | 357 | | 547 |
| Cadmium | 2.07E-04 | 2.00E-04 | 2.04E-04 | 5.87E-04 | 5.00E-04 | 5.00E-04 | 2.00E-04 | 3.98E-04 |
| Calcium | 5050 | 5010 | 5030 | | | | | 5030 |
| Chromium | 2.50E-04 | 0.001 | 6.25E-04 | 0.001 | 0.0025 | 0.0025 | 0.001 | 0.00153 |
| Chromium (VI) | | | | | | | | 0.00209[a] |
| Cobalt | | | | | | 0.0025 | | 0.0025 |
| Copper | 2.50E-04 | 0.001 | 6.25E-04 | 0.00261 | 0.00553 | 0.0025 | 0.001 | 0.00245 |
| Iron | 0.025 | 0.1 | 0.0625 | 0.1 | 0.25 | | 0.1 | 0.128 |
| Lead | 1.00E-04 | 4.00E-04 | 2.50E-04 | 4.00E-04 | 0.001 | 0.001 | 4.00E-04 | 6.10E-04 |
| Magnesium | | | | | | | | 769[a] |
| Manganese | 0.293 | 0.28 | 0.287 | 0.349 | 0.631 | 1.73 | | 0.749 |
| Mercury | 1.05E-05 | 1.05E-05 | 1.05E-05 | 1.22E-05 | 3.60E-05 | 2.09E-05 | 1.72E-05 | 1.94E-05 |
| Molybdenum | 0.14 | 0.134 | 0.137 | 0.373 | 0.195 | 0.11 | 0.419 | 0.247 |
| Nickel | 0.00803 | 0.00979 | 0.00891 | 0.00776 | 0.0025 | 0.0126 | 0.0291 | 0.0122 |
| Selenium | 0.074 | 0.0689 | 0.0715 | 0.104 | 0.121 | 0.0822 | 0.109 | 0.0975 |
| Silver | 5.00E-05 | 2.00E-04 | 1.25E-04 | 2.00E-04 | 5.00E-04 | 5.00E-04 | 2.00E-04 | 3.05E-04 |
| Sodium | 277 | 259 | 268 | | | | | 268 |
| Thallium | 0.00664 | 0.00556 | 0.0061 | 0.00565 | 0.00685 | | | 0.00620 |
| Tin | | | | | | | | 0.1[b] |
| Titanium | | | | | | | | 0.01[b] |
| Vanadium | | | | | | 0.0025 | | 0.0025 |
| Zinc | 5.00E-04 | 0.002 | 0.00125 | 0.002 | 0.005 | 0.005 | 0.002 | 0.00305 |

a: Data gap filled with similar plant-specific primary wastewater treatment system effluent data

b: Data gap filled with *Technical Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA, 2013)

TABLE 3
Merrimack Influent and Effluent Average Concentrations and Removals in mg/L * TWF

| Analyte | TWF | FGD Purge (Phys/Chem Influent) | Phys/Chem Effluent (VCE Influent) | Phys/Chem Removal | VCE Removal |
|---|---|---|---|---|---|
| Ammonia | 0.00111 | 0.00579 | 0.00119 | 0.0046 | 0.00119 |
| Nitrate Nitrite as N | 0.0032 | 0.105 | 0.249 | - | 0.249 |
| Chloride | 2.43E-05 | 0.243 | 0.241 | 0.00211 | 0.241 |
| Sulfate | 5.60E-06 | 0.0162 | 0.00672 | 0.00952 | 0.00672 |
| Cyanide, Total | 1.12 | 0.0130 | 0.0130 | - | 0.0130 |
| Aluminum | 0.0647 | 13 | 0.00645 | 12.8 | 0.00645 |
| Antimony | 0.0123 | 0.000185 | 1.13E-05 | 1.74E-04 | 1.13E-05 |
| Arsenic | 4.04 | 0.902 | 0.0326 | 0.869 | 0.0326 |
| Barium | 0.00199 | 0.00101 | 0.000478 | 5.27E-04 | 0.000478 |
| Beryllium | 1.06 | 0.0107 | 0.000937 | 0.00977 | 0.000937 |
| Boron | 0.00834 | 1.74 | 4.56 | - | 4.56 |
| Cadmium | 23.1 | 0.449 | 0.00920 | 0.440 | 0.00920 |
| Calcium | 0.000028 | 0.136 | 0.141 | - | 0.141 |
| Chromium | 0.0757 | 0.0482 | 0.000115 | 0.0481 | 0.000115 |
| Chromium (VI) | 0.517 | 0.372 | 0.00108 | 0.371 | 0.00108 |
| Cobalt | 0.114 | 0.0100 | 0.000286 | 0.00971 | 0.000286 |
| Copper | 0.635 | 0.207 | 0.00156 | 0.205 | 0.00156 |
| Iron | 0.0056 | 0.674 | 0.000718 | 0.674 | 0.000718 |
| Lead | 2.24 | 3.72 | 0.00137 | 3.72 | 0.00137 |
| Magnesium | 0.000866 | 0.825 | 0.666 | 0.159 | 0.666 |
| Manganese | 0.0704 | 1.68 | 0.0528 | 1.62 | 0.0528 |
| Mercury | 117 | 30.2 | 0.00227 | 30.2 | 0.00227 |
| Molybdenum | 0.201 | 0.0250 | 0.0497 | - | 0.0497 |
| Nickel | 0.109 | 0.115 | 0.00133 | 0.114 | 0.00133 |
| Selenium | 1.12 | 3.07 | 0.109 | 2.96 | 0.109 |
| Silver | 16.5 | 0.00455 | 0.00502 | - | 0.00502 |
| Sodium | 5.49E-06 | 0.00336 | 0.00147 | 0.00189 | 0.00147 |
| Thallium | 1.03 | 0.0165 | 0.00637 | 0.0101 | 0.00637 |
| Tin | 0.301 | 0.00346 | 0.0301 | - | 0.0301 |
| Titanium | 0.0293 | 0.0178 | 0.000293 | 0.175 | 0.000293 |
| Vanadium | 0.035 | 0.0120 | 8.75E-05 | 0.0120 | 8.75E-05 |
| Zinc | 0.0469 | 0.201 | 0.000143 | 0.201 | 0.000143 |
| Total | | **57.6** | **6.2** | **54.5** | **6.2** |

- : Removal for effluent with values greater than influent was not counted

TABLE 4
Merrimack Treatment System Benefits

| | **Flow (gpy)** | **Removal (mg/L * TWF)** | **Removal (TWPE per year)** |
|---|---|---|---|
| Physical/Chemical | 9,250,560 | 54.5 | 4,205 |
| VCE | 9,250,560 | 6.2 | 478 |

TWPE - Toxic Weight Pound Equivalent

## Cost Estimate

Cost data were obtained from PSNH Merrimack. Costs were annualized based on a 20 year plant life span at a 7% interest rate. Table 5 summarizes the annualized cost in current dollars and 1981 dollars.

This system cost reflects its construction as a component of the FGD Scrubber/Clean Air Project. The VCE costs would likely increase if built as a standalone system.

TABLE 5
PSNH Merrimack Cost for Physical/Chemical and VCE Treatment Technologies

| | Capital Cost, [million dollars] | Operation & Maintenance, [million dollars per year] | Total Annualized, [million dollars per year] | Capital Cost, [1981 million dollars] | Operation & Maintenance, [1981 million dollars per year] | Total Annualized, [1981 million dollars per year] |
|---|---|---|---|---|---|---|
| Physical/Chemical | 19.3 | 1.8 | 3.7 | 7.3 | 0.7 | 1.4 |
| VCE | 35.3 | 2.4 | 5.7 | 13.4 | 0.9 | 2.2 |

Note: Capital and operating costs provided by PSNH Merrimack

## References

EPA, 2013. U.S. Environmental Protection Agency. *Technical Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. EPA-821-R-13-002, April 19.

ERG, 2009. Eastern Research Group, Inc. *Memorandum: Technology Option Loads Calculation Analysis for Steam Electric Detailed Study*. To: Public Record for the Effluent Guidelines Program Plan 2009/2010. From: TJ Finseth, ERG. EPA-HQ-OW-2008-0517-